VOLUME VISUALIZATION OF SPATIAL DATA

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ABSTRACT – Volume visualization is fundamental for many scientific investigations. The representation of natural phenomena properties and their changes helps us to understand their spatial behavior and it also results in relevant scientific information. Besides, it allows a better use of available data to make such analysis. This paper is about volume visualization of spatial data. It aims at showing new possibilities to visualize three-dimensional data that represents natural phenomena such as geology, soils, geophysics, seismic and the like. The use of volumes in the evaluation processes allows one to visualize and to represent the spatial variation of the phenomenon properties, thus incorporating the third dimension in cartography. The volume visualization is a branch of scientific visualization that has shown a fast growth and its goal is to comprehend the internal structure and the behavior of three-dimensional objects. Volume visualization depends on the interaction. We must, therefore, interact with the volume through rotations, cuts and other forms of graphic manipulation, seeking for the complete information. The procedures for representation and visualization of spatial data imply all sorts of activities from the acquisition of data to the generation of the final product. Such activities define the operational steps of the chosen methodology. Then, the methodological development implies: 1. The acquisition of three-dimensional data; 2. The organization of such data; 3. Three-dimensional interpolation; 4. Volume formation and visualization. The data used for this research refer to soil's physical, chemical and morphological properties. They are the result of morphological description and lab analysis from field collected samples. Three-dimensional data of soil's properties were discretely taken and, in order to know the values of such properties in non sampled points, they must be interpolated. The study area for this research is part of a small town called Castro in the State of Paraná, south of Brazil, and it has an area of about 215.000 m^2. Representation and volume visualization of spatial phenomena demand the use of computer systems which are able to deal with such complexity. Therefore, to have an adequate volume visualization of soil's properties, it is necessary to have a three-dimensional Geographic Information System (SIG-3D) and a software for volume visualization. This research was done in a SIG-3D environment using the GRASS GIS, 6.1 cvs version and the software used for volume visualization was the Vis5D, both for Linux Operational System. For soil's evaluation process it is necessary to analyze qualitative and quantitative data. The representations of soil's information are usually done through soil maps, toposequence profiles, isoline maps, surface maps, block diagrams and graphics. These representations describe patterns on surfaces instead of distribution of spatial attributes of subsurface and then, limit the complete visualization of variations in volume. One might then consider that to visualize three-dimensionally soil's properties is an important pace for the study of such phenomenon. The outcome of volume representations of physical, chemical and morphological properties allows visualizing and representing the spatial variation of these properties and it is also a new way to visualize the soil and a new source of knowledge to the study of this phenomenon.

Key-words: volume visualization, three-dimensional interpolation, three-dimensional geographic information systems.

1 Introduction

The process of analysis and modeling of natural phenomena depends on reliable and detailed information which describe spatial distributions of several elements related to them. Properties representation of such phenomena and their variations help in understanding its spatial behavior and in extracting basic scientific information. It also helps in getting a better performance of available data for analysis.

Most of natural phenomena, related to pedology (soils), geology, geophysics and others, have properties which vary in all spatial dimensions. Usually, information about these phenomena's properties is obtained from a limited number of sample points. These data are submitted to analysis and descriptions and then they are extended to the whole area in order to represent the continuous structures and spatial geometry of such phenomena. This can be done by means of mathematical modeling through interpolation.

Scientific visualization concerns to data and information investigation in order to have the correct understanding of the analyzed phenomena (EARNSHAW & WISEMAN, 1992). Volume visualization is a branch of scientific visualization that has shown a fast growth and through which it is possible to extract information from a set of volumetric data (KAUFMAN, 1996). Volume visualization aims at understanding the internal structure and the complex behavior of three-dimensional objects (FUJISHIRO et al., 1996).

Volume visualization demands volumetric data. Volumetric data is a set A of samples (x, y, z, w) which represents the value w of a certain attribute in the three-dimensional position (x, y, z) (KAUFMAN, 1996). Manipulating data in volume visualization is a dynamic process of analysis. Then, as a premise, it is necessary to interact with the volume through rotations, cuts and other forms of graphic manipulation, in order o get the intended information.

For soil's evaluation process, it is necessary to analyze qualitative and quantitative data.

Having the morphological properties (qualitative criteria) and the physical and chemical properties (quantitative criteria) of soil's horizons one is able to identify and classify soils. Soil's horizons are distinguished by their characteristics and properties and their succession from the surface to the lithosphere (rock) is called soil profile (KIEHL, 1979). The data used for this research refer to soil's physical, chemical and morphological properties. They are the result of morphological description and lab analysis from field collected samples.

The representations of soil's information are usually done through soil maps, toposequence profiles, isoline maps, surface maps, block diagrams and graphics. These representations describe patterns on surfaces instead of spatial distribution of sub-surface attributes and then they limit the complete visualization of attributes variations in the three-dimensional space. One may say that to visualize soil's properties three-dimensionally is an important step towards for the study of such phenomenon.

This paper deals with spatial data modeling and representation. The concepts and techniques of volume visualization which were developed in scientific visualization are applied in the cartographic representation of soil's properties.

2 Methodology

Volume visualization presupposes volume formation that demands volumetric data. Volumetric data are then generated by means of three-dimensional interpolation and data of attributes in their three-dimensional positions are obtained from samples collected in the studied area (IESCHECK, 2006).

The procedures for data acquisition, representation and volume visualization of soil's properties define the operational steps of the chosen methodology. Then, the methodological development implies the acquisition of three-dimensional data, organization and codification of data, three-dimensional interpolation, and volume formation and visualization.

2.1 Study area

The study area for this research is part of a small town called Castro in the State of Paraná, in the South of Brazil (fig. 1) and it is about 215.000 m^2 large. This area is characterized by different types of soils and it is mainly used for agricultural activities.

Soil can be defined as a natural body consisting of layers or horizons of mineral and organic constituents of variable thickness, which differ from the parent material in their morphological, physical, chemical, and mineralogical properties. In order to support the activities developed in this research and considering the relief as the spatial reference for determination of soil's sample depth, a digital topographic map of the area, with contour lines at 20 cm vertical interval, was generated.

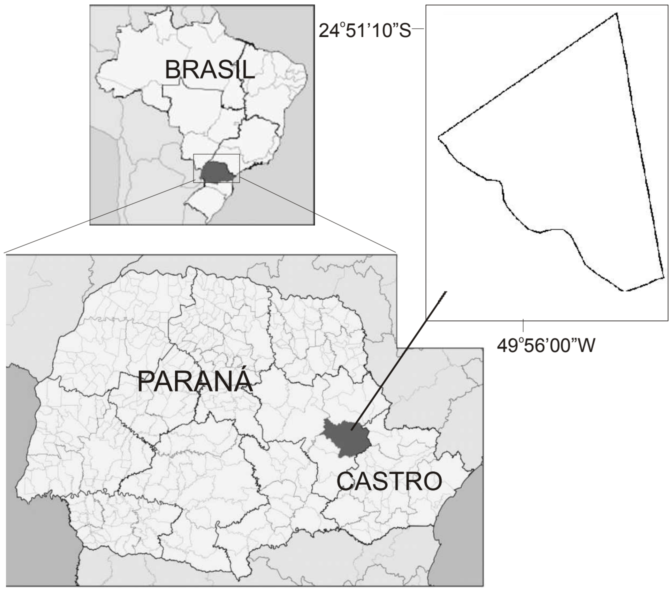

Figure 1. Map of study area

2.2 Data Acquisition

The soil's samples were collected from a set of monoliths. These monoliths were spatially located as a regular, or almost regular, 30 meters resolution grid (fig. 2). All three-dimensional coordinates of the grid points were determined in a field survey.

The morphological characterization of the soils of the study area was determined by morphological description of those monoliths. The morphological characteristics observed were the soil's horizons, colors and structures (type, class and level).

In order to develop the physical and chemical analyses it was necessary to collect new samples. These samples were collected in nine soil's profiles. The locations of these profiles were defined base on a 1:10.000 soils map of the area (fig. 3),.

The soil's physical and chemical properties were defined by laboratory analyzes. The physical soil components were represented by the following attributes: density, volumetric humidity, porosity (total and macro), available water and texture. And the physical soil components were represented by the following attributes: pH ($CaCl_2$), organic constituents, bases and CTC.

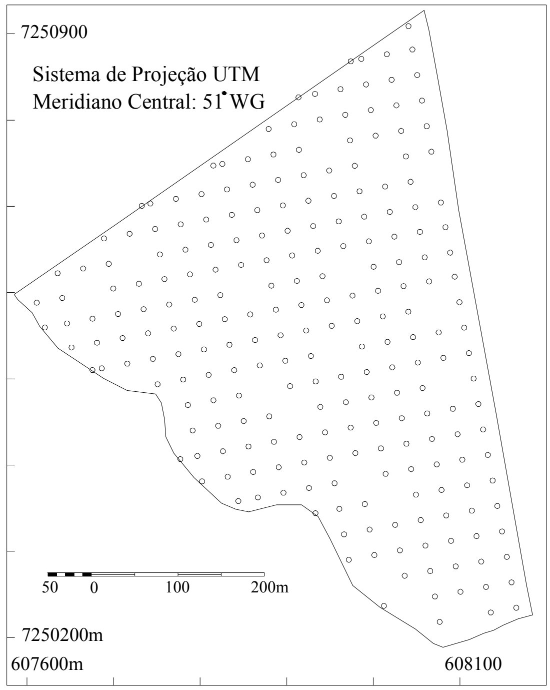

Figure 2. Map of Sampling Points - Monoliths

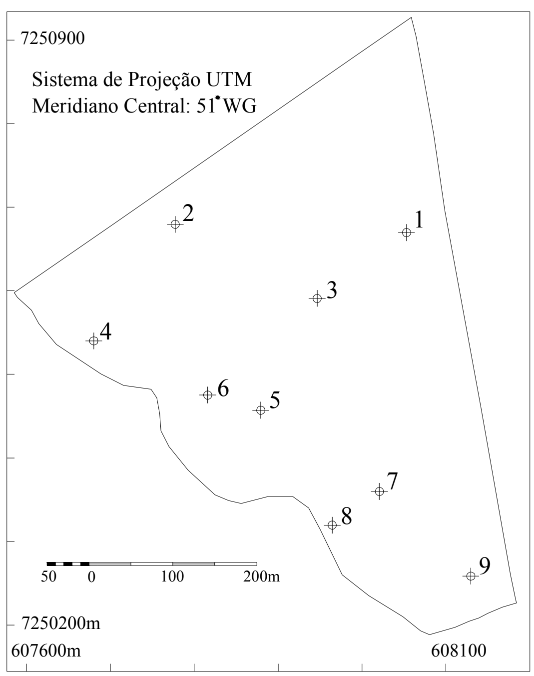

Figure 3. Map of Sampling Points - Profiles

2.3 Interpolation and Volume Visualization

Three-dimensional data of soil's properties were discretely obtained from sample points measured in the field and they were interpolated for volume representation in the spatial domain. As I have mentioned before, these data are of qualitative and quantitative nature.

Because of data's qualitative attributes it is necessary to codify them in order to have its computational representation. Computational interpolation of qualitative attributes demands data quantification and thus it is necessary to define numerical codifications to identify each class of types of horizons and colors of classes of soil. Codification for representation of types of horizons is done in an increasing number sequence from surface to the last horizon. For colors, a mnemonic codification is done so that in checking the attributes straightly over the image one identifies by association the designation of the color in Munsell's system. Qualitative data resultant of morphological description corresponds to the identification of types of horizons and their colors.

As data from lab analyzes are of quantitative nature and they represent the values of soil's physical and chemical properties it is not necessary to codify them. After data's organization and codification, they are processed in order to generate volumes. The process of volume's formation implies a transformation of three-dimensional point data into volumetric data. For such procedure I used the three-dimensional data interpolation by regularized spline with tension method in three dimensions (3D-RST), implemented in GRASS GIS (*Geographic Resources Analysis Support System*).

Visualizations and manipulations of volumes are done by means of Vis-5D. This software has interactive tools which allow to generate iso-surfaces in three-dimensional space as well as to do horizontal and vertical cuts, and to visualize these cuts through area representations with colors and limiting iso-lines among other forms of graphic manipulation. Besides, Vis-5D can be used according to GPL (*General Public License*) for Linux and Unix Operational Systems.

3. Results

After volumes were generated and exported to Vis5D, the potentiality of these new proposals of cartographic representation for volume analyzes could be verified. By means of interaction tools and graphic manipulation, volume's information can be shown through different ways and points of view.

Data from morphological description are of qualitative nature while data from physical and chemical analyzes are of quantitative nature. From morphological propertie's data representations of different types of horizon and soil's colors for each horizon are generated besides the definition of horizon's limits. From physical analyzes results I could create visualizations of the following properties: soil's density; volumetric humidity at 6 kPa, volumetric humidity at 10 kPa, volumetric humidity at 100 kPa and volumetric humidity at 1500 kPa; total and macro porosity; available water; and texture. From chemical analyzes I used data to visualize the following soil's properties: pH, bases sum, organic material and CTC.

At this point I present the volume visualization of soil's density. The figure 4 shows the volume visualization of 3-D isosurfaces that represents the densities of 1.110 kg/dm^3, 1.079 kg/dm^3, 1.048 kg/dm^3, 1.021 kg/dm^3, 1.016 kg/dm^3 e 0.985 kg/dm^3. These isosurfaces were generated using the interactive tools of Vis5D.

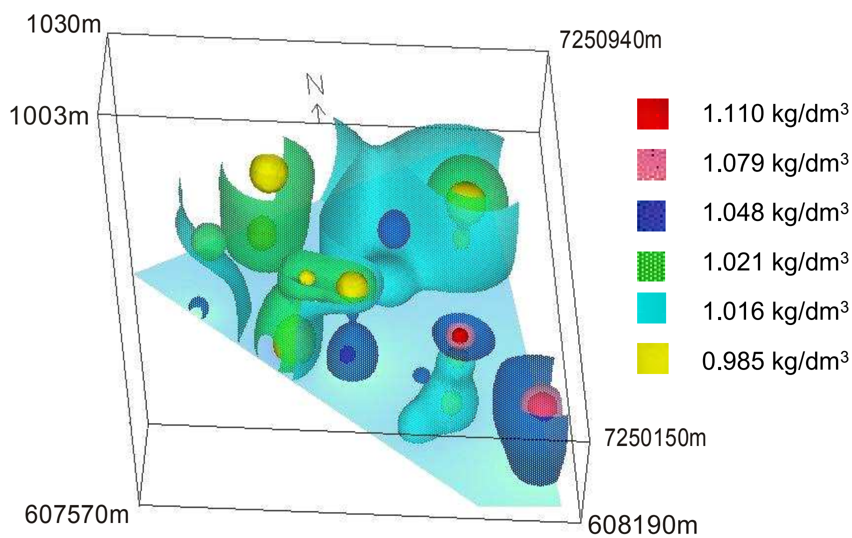

Figure 4. Volume Visualization of Soil's Density

4. Conclusions

Volume visualization presupposes interaction to explore information. Therefore, one must interact with the resulting volume in order to explore the information in an absolute manner so that it is possible to analyze it in a dynamic way.

The efficiency of results depends on integrated action of experts in the field of cartographic and soil's visualization. Results obtained from this research confirm the initial hypothesis according to which representation and visualization of soil's volumes allow one to have a more complete knowledge of the area than the one obtained from analyzes of cartographic representations in bi-dimensional maps or surfaces. It is, then, an important tool for soil's evaluation since it increases the potentiality of use of available data.

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